Laser Bioeffects and Protection

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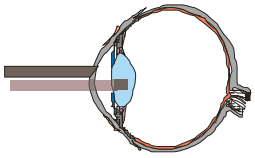
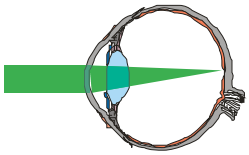
- **Eye**

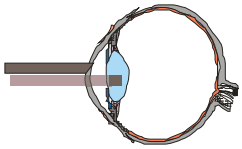
Ultraviolett
100 nm - 400 nm



Visible + near IR
400 nm - 1400 nm



Far Infrared
1400 nm - 1mm



- **Skin**

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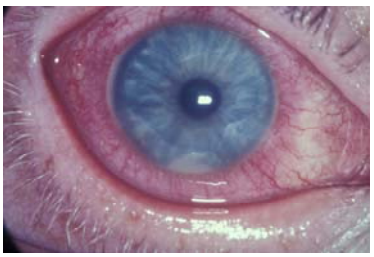
UV: Photokeratitis

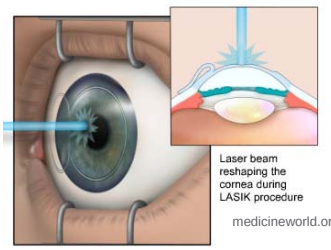


courtesy of Per Söderberg

Cataract

courtesy of University of Michigan, Kellogg Eye Center

Pulses: Ablation



medicineworld.org

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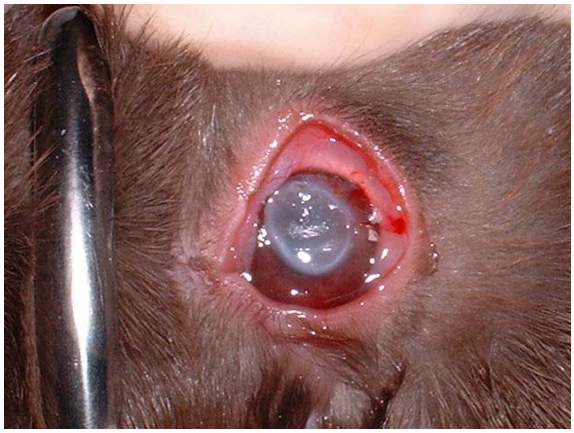
Far IR



Courtesy of Tsutomu Okuno

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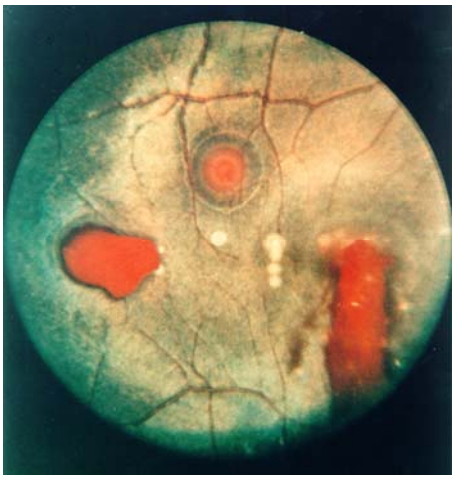

courtesy of Joe Zuclich

Effects

superthreshold:
***Accidents*,**
Medical

at threshold: ***Exposure limits***

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Threshold Experiments

Uncertainty: ~ 20 %

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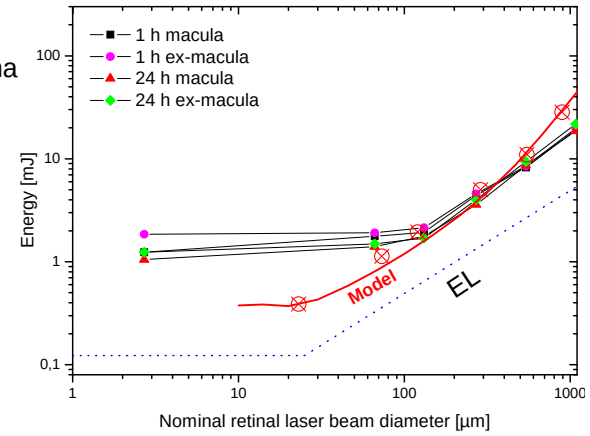
Safety Factor

- 10 for small spots and retina
- 3 for larger spots retina
- 3 for UV



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Bioeffect Dependencies

- **Wavelength:** **100 nm to 1 mm** ***4 orders***
- **Pulse duration:** **10^{-14} s to 10 000 s** ***18 orders***
- **Spot size:** **10 µm to 1 m** ***5 orders***
- **Power:** **µW to TW** ***21 orders***

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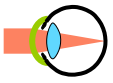
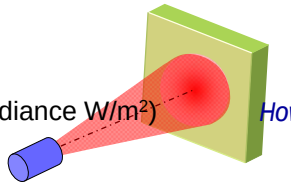
Bioeffect *for Laser AND broadband radiation*

Depends on

- Wavelength 

» Location of absorption   *Where?*

» Type of interaction (thermal, photochem.) *How?*

- Pulse duration 
- Power/spot area = power density (irradiance W/m²)  *How strong?*

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„Temporal concentration“ – pulse duration

„Spatial concentration“ – spot size

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One Photon (light particle) has certain energy

This energy has „action“ on tissue
(heating, chemical change)

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Power = Photons emitted per time

↓

Power = Energy emitted per time

$$\text{Power} = \frac{\text{Energy}}{\text{Time}}$$

Energy = Power x Time

$$1\ \text{Watt} = \frac{1\ \text{Joule}}{1\ \text{Second}}$$

1 Joule = 1 Ws

Photon concentration

How many photons?

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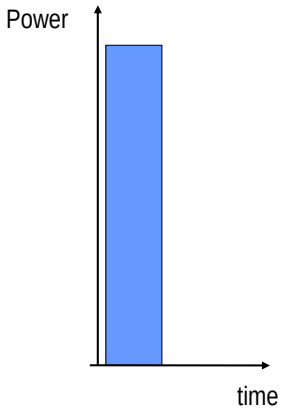
1 Joule Energy
10 ns Pulse duration (= 10^{-8} s)



$$\frac{1 \text{ Joule}}{10^{-8} \text{ Second}} = 10^{8} \text{ Watt} = 100 \text{ MW}$$

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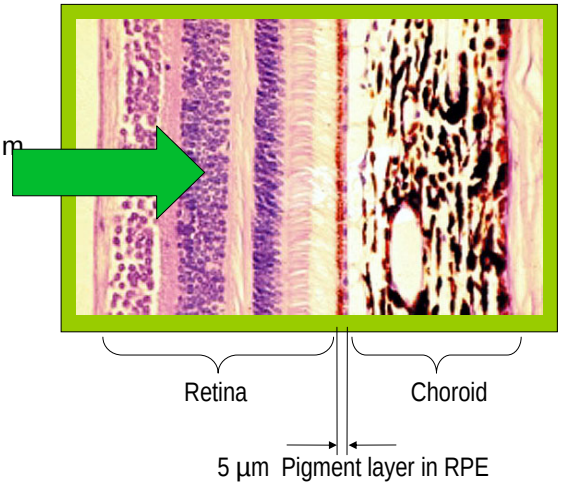
Bioeffect < ~ 10 µs: Microcavitation

Melanosomes
(pigment particle)
in Retinal Pigment Epithelium
(RPE)

„Vapour Bubble“

„Thermomechanical“



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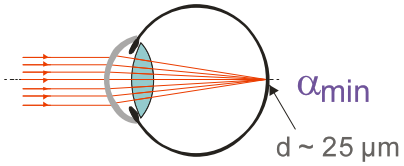
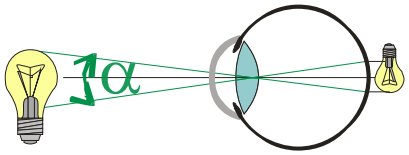
Temporal Concentration

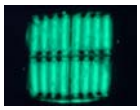
Spatial Concentration

- **Laser: „point source“** (usually)



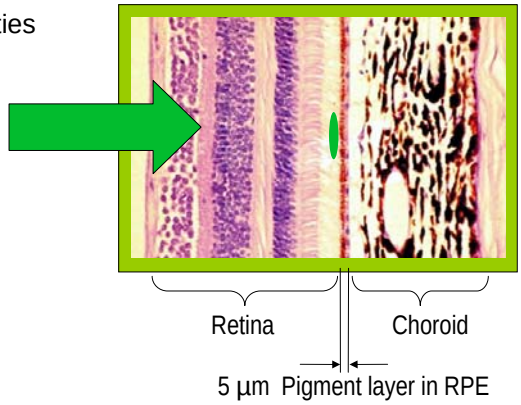
- **Broadband: „extended source“**





Absorbing layer: 5 µm „thick“

- Very high power densities
- (W/m^3)



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Temporal concentration

Spatial concentration

→ low damage thresholds!

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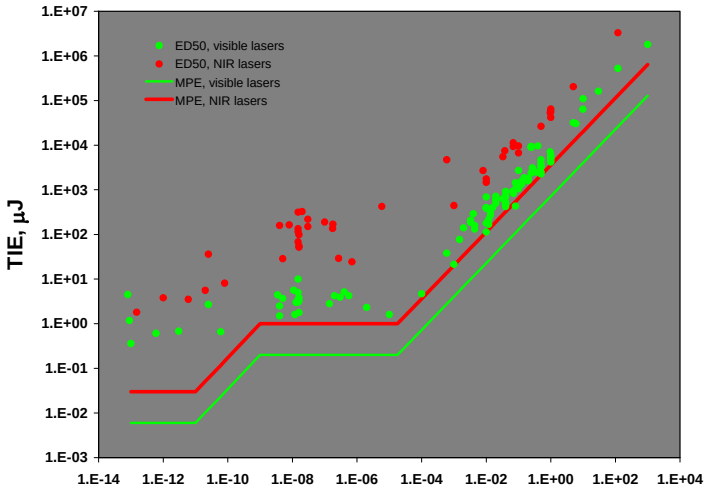

Plot courtesy of DJ Lund

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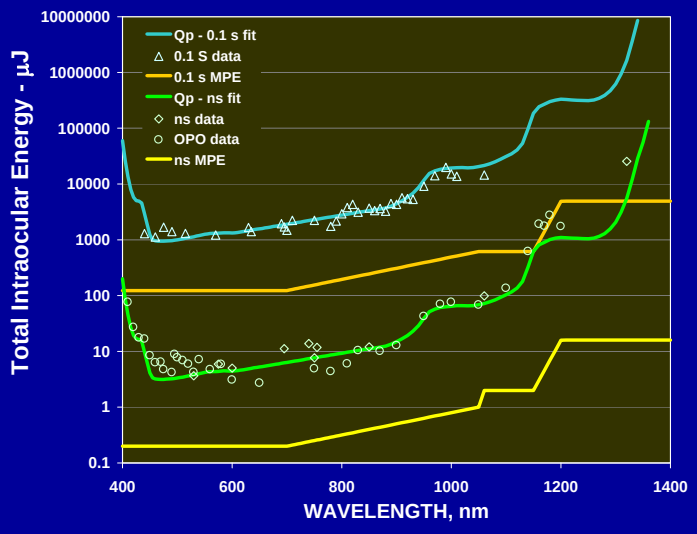
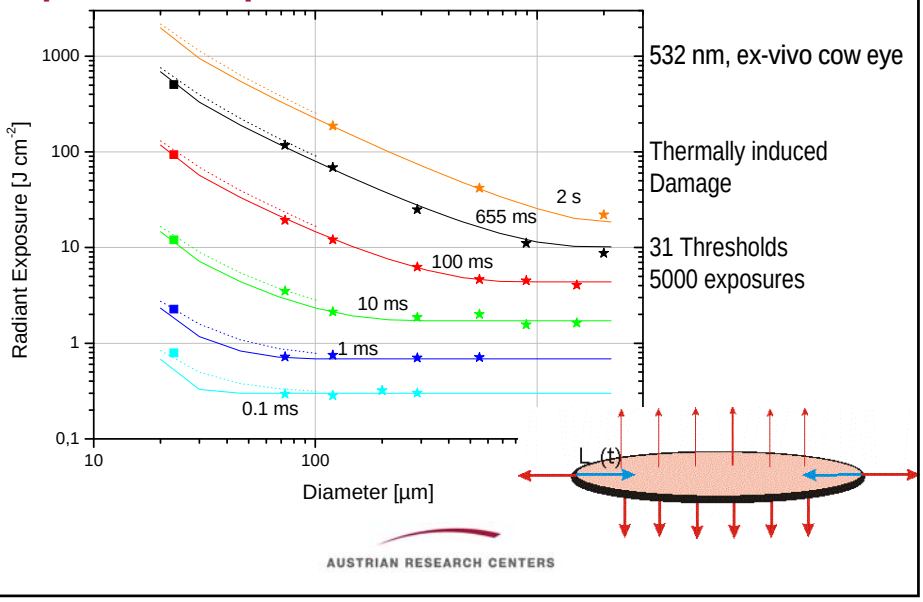
Wavelength Dependence Retina



David J. Lund

Spot Size Dependence



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Temporal concentration (high peak powers):

-> temperature rise
„Thermal damage“

Low powers (no heating) but long enough to accumulate photons

for blue and UV:
„Photochemical damage“

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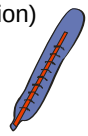
Thermal

Increase of Temp

critical Temperature → damage

(„Burn“, coagulation, enzyme inactivation)



Photochemical

„High Energy“ Photons
(UV, blue)

Chemical Bonds are changed, Molecules activated
→ “Phototoxic“

(e.g. Sunburn)

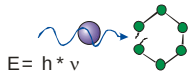
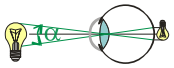


Photo-chemical Effects

- Vision (Isomerisation)
- Photo-film exposure
- Vitamin-D production UV-B
- „Sunburn“ of skin and cornea
- Photoretinitis („Sunburn“ of Retina, Blue light hazard“)

Thermal

mainly by **pulses**

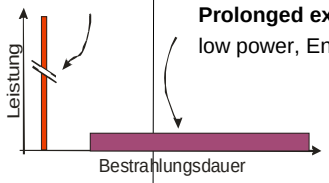
spot size dependence 

wavelength dependence:
optical absorption

Photochemical

Additivity of microdamages
„Dose“ relationship – J/m²

Prolonged exposures,
low power, Energy adds up



NO spot size dependence

strong wavelength dependence
„action spectrum“

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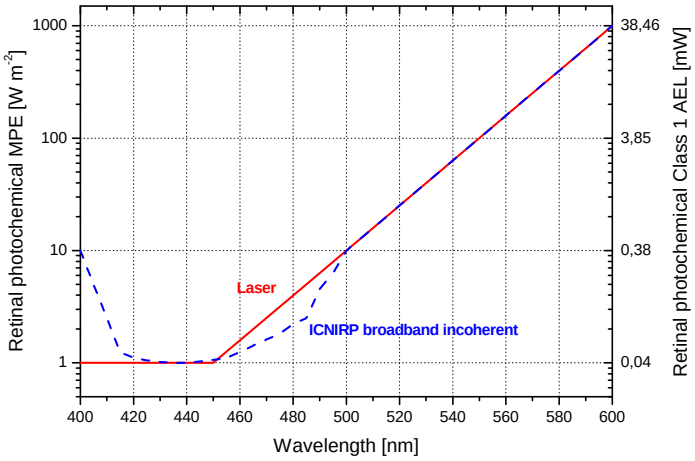
Wavelength dependence – photochem Retina



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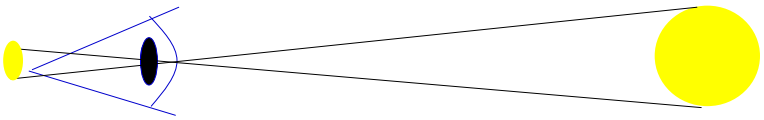
Photochemical and Thermal „compete“

- wavelength
- pulse duration
- spot size

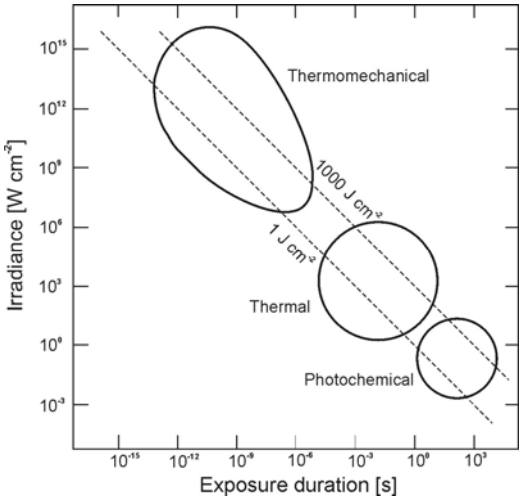
Sun (high in sky)

- naked eye:
- photochemical damage (blue light)



- telescope:
- thermal damage within ~ 100 ms

Overview Bioeffects



From: „Laser Safety" Henderson & Schulmeister

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